



FEDERAL REPUBLIC OF GERMANY

Priority Certificate Regarding the Filing  
of a Patent Application

Serial No.: 102 44 234.7  
Application Date: September 23, 2002  
Applicant/Owner: Dr. Johannes Heidenhain GmbH,  
Traunreut/DE  
Title: Position Measuring Instrument  
IPC: G 01 B, 21/100

The attached papers constitute a correct and accurate  
reproduction of the original documents of this patent  
application.

[Ribbon and Seal  
Office of the German  
Patent and Trademark  
Office]

München, July 31, 2003  
German Patent and Trademark  
The President  
By

s/[Illegible]  
t/[Illegible]

The instant papers constitute a substantially correct translation  
of the attached Priority Certificate and text of German  
Patent Application DE 102 44 234.7 in the name of Dr.  
Johannes Heidenhain GmbH.

Olaf Bexhoeft

Olaf Bexhoeft  
5316 Little Falls Road  
Arlington, VA 22207-1522  
USA

August 30, 2005



## Position Measuring Instrument

The invention relates to a position measuring instrument for determining the absolute position, in accordance with claim 1, and to a method for absolute position measurement, in accordance with claim 12.

In many fields, for determining the position of two bodies moved toward one another, absolute position measuring instruments are increasingly being used. Absolute position measuring instruments have the advantage over systems that measure purely incrementally that in every relative position, even after the energy supply has been interrupted, a correct position information can be output immediately.

The absolute position is embodied by a code, which is arranged in a plurality of tracks extending parallel to one another, for instance in the form of a gray code.

Arranging the position information in a single code track, with code elements in line with one another in the measurement direction, is especially space-saving. The code elements are disposed in line with one another in a pseudo-random distribution, so that a certain number of successive code elements are disposed in line with one another in a pseudo-random distribution, so that a certain number of successive code elements each form one bit pattern that unambiguously defines the absolute position. When the scanning instrument is shifted by a single code element, a new bit pattern is already formed, and over the entire measurement range to be detected in absolute form, a sequence of different bit patterns is available. This kind of sequential code is known as a chain code or a pseudo-random code.

In both multitrack and single-track absolute coding, it is a problem to achieve a space-saving layout on the one hand and high resolution on the other.

To enhance the resolution in sequential absolute coding, it is usual to provide at least one incremental graduation in addition. The period of this incremental graduation must be adapted to the length of a code element, or in other words to the maximum possible increment width or resolution of the code. As explained in German Patent Disclosure DE 41 23 722 A1, the graduation period or incremental graduation should be selected to exactly match the increment width of the code. To further enhance the resolution, a second incremental track is required, whose graduation period is a fraction of the graduation period of the first incremental track. To enhance the resolution of the absolute position measurement, that is, the subdivision of the increment width of the code, a plurality of incremental tracks disposed side by side are thus necessary.

This arrangement has the disadvantage that a space-saving layout is not possible, and that the scanning elements of the two incremental tracks are spaced apart from one another perpendicular to the measurement direction, and as a consequence the arrangement is vulnerable to rotations of the scanning unit (known as moiré fluctuations). Upon rotations between the scanning unit and the incremental graduations, the requisite synchronization of the scanning signals, derived from the two incremental tracks, is no longer assured.

For this reason, European Patent Disclosure EP 1 111 345 A2 has proposed disposing, besides the absolute code, only a single incremental graduation, which however has two

different graduation periods. A detector arrangement is designed to generate a first incremental signal with a coarse signal period and a second incremental signal with a fine signal period, that is, incremental signals that are required for synchronization in the apparatus of DE 41 23 722 A1. A prerequisite for this synchronization is an interpolation of the incremental signals with the coarse signal period, which is why EP 1 111 345 A2 lists various provisions for filtering, in order to derive an interpolatable incremental signal with the coarse signal period from the incremental track. The provisions for generating two highly interpolatable incremental signals of EP 1 111 345 A2 require relatively great effort and expense.

It is therefore the object of the invention to disclose an absolute position measuring instrument which is compact in structure and with which a high-resolution absolute position measurement that is as accurate as possible can be achieved in a simple way.

This object is attained by the characteristics of claim 1.

It is also the object of the invention to disclose a method for determining an absolute position with which the most highly accurate and high-resolution position measurement possible is enabled.

This object is attained by the characteristics of claim 12.

Advantageous embodiments of the invention are recited in the dependent claims.

The invention will be described in further detail in conjunction with the drawings.

Fig. 1 schematically shows a position measuring instrument with a code track and an incremental track;

Fig. 2 shows the arrangement of detector elements relative to the code track and to the incremental track of the position measuring instrument of Fig. 1 for generating scanning signals;

Fig. 3 shows a device for evaluating the scanning signals;

Fig. 4a shows the scanning of the incremental track in a first position;

Fig. 4b shows the scanning of the incremental track in a second position;

Fig. 4c shows the scanning of the incremental track in a third position;

Fig. 4d shows the scanning of the incremental track in a fourth position;

Fig. 5 shows a table of association for evaluating the scanning signals of the incremental track;

Fig. 6 shows a scanning region with the code track and the scanning signals of the incremental graduation that are associated with the code track;

Fig. 7 shows the principle of scanning the code track;

Fig. 8 shows the generation of a control signal from the incremental track for scanning the code track;

Fig. 9a shows a first scanning position for scanning the code track;

Fig. 9b shows a second scanning position for scanning the code track;

Fig. 9c shows a third scanning position for scanning the code track; and

Fig. 9d shows a fourth scanning position for scanning the code track.

In Fig. 1, a position measuring instrument designed according to the invention is illustrated in the form of a

length measuring instrument. This position measuring instrument operates by the optical scanning principle, in which a scale 1 is scanned by a scanning device 2, which is arranged to be movable in the measurement direction X relative to the scale 1.

The basic layout is equivalent to a conventional position measuring instrument as shown for instance in DE 41 23 722 A1. The scanning device 2 includes a light source 3, whose light, via a collimator lens 4, illuminates a plurality of tracks 5 and 6. The light is modulated as a function of position by the tracks 5, 6, so that downstream of the tracks 5, 6, a position-dependent light distribution occurs that is detected by the detector unit 7 of the scanning device 2.

The track 5, in the example shown, is a sequential code, which comprises a series of equal-length code elements C1, C2, C3 disposed in line with one another in the measurement direction X. The length of a code element C1, C2, C3 is equivalent to the increment width within which an absolute position can be determined unambiguously.

To make the absolute position measurement especially secure against malfunction, each code element C1, C2, C3 in turn comprises two partial regions C1A, C1B; C2A, C2B; C3A, C3B of equal length in the measurement direction X, disposed side by side and in immediate succession with one another and embodied in complementary form to one another. Complementary here means that they have inverse properties; that is, for the optical scanning principle, they are transparent and nontransparent, or with incident-light scanning, they are reflective and nonreflective, respectively. Such a code is also known as a Manchester code.

The detector unit 7 comprises a detector arrangement 7.5, with a series of detector elements D1-11 (shown in

detail in Figs. 2 and 7) disposed in the measurement direction X. In every relative position, at least one detector element D1-D11 is associated unambiguously with each partial region C1A, C1B of a code element C1, so that in every relative position of the detector unit 7 relative to the code track 5, a scanning signal S is obtained from each partial region C1A, C1B. These scanning signals S are delivered to an evaluation device 10, which assigns a digital value B = 0 or B = 1 to each code element C1, C2, C3. In the Manchester code 5, the digital value B is dependent on the order of the partial regions C1A and C1B. For instance, the order C1A = opaque and C1B = transparent means the digital value is B1 = 0, and the order C2A = transparent and C2B = opaque means the digital value is B2 = 1. An especially malfunctionproof formation of the digital value B is achieved by finding the difference between the scanning signals of successive partial regions C1A, C1B of a code element C1, as will be described in further detail hereinafter.

The detector arrangement 7.5 is designed for simultaneously scanning a plurality of successive code elements C1, C2, C3. A series of a plurality of digital values B1, B2, B3 yields a code word CW, which defines the absolute position. Upon a displacement of the detector unit 7 relative to the scale 1 by the width or length of a code element C1, C2, C3, a new code word CW is generated, and over the distance or angle to be measured in absolute form, many different code words CW are formed.

To increase the resolution, or in other words further subdivide an increment width of the absolute position measurement, an incremental graduation 6 is disposed parallel to and next to the code track 5. The length of one

graduation period  $P$  is a fraction of the length of one code element  $C1, C2, C3$ .

Fig. 2 shows a detail of the position measuring instrument of Fig. 1 schematically. This illustration clearly shows the association of the tracks 5, 6 with one another and with the detector arrangements 7.5 and 7.6.

The incremental graduation 6 is scanned in a known manner; one detector element A, B, C, D is assigned each graduation period  $P$ , at a mutual spacing of one quarter of the graduation period. The detector elements A, B, C, D generate four interpolatable sine-wave analog signals A1-D8 in phase quadrature. Eight graduation periods P1-P8 are disposed parallel to the code element C2. The detector element arrangement A, B, C, D is located in each graduation period P1-P8. In-phase detector elements A, B, C, D of all the graduation periods P1-P8 are added together, so that a  $0^\circ$  signal PA, a  $90^\circ$  signal PB, a  $180^\circ$  signal PC, and a  $270^\circ$  signal PD are generated. These four analog scanning signals PA, PB, PC, PD in phase quadrature are subdivided in an interpolation unit 9 in a known way, as a result of which a further absolute position information Q is obtained, which subdivides a length of one graduation period  $P$  into small measuring increments. Now the problem is that the interpolation value Q provides absolute unambiguous resolution for only a fraction of the length of one code element C2, or in other words the fraction of a measurement range. For unambiguous combination of the position values CW and Q to make one common absolute position measurement value, a further position determination is therefore necessary.

The invention is now based on the discovery that for this purpose it is sufficient to observe the shift of one of

the periods P1-P8 over the length of one code element C2 - that is, the increment width of the absolute position measurement. To that end, within one of the graduation periods P1-P8, a reference marking R is provided. The detector arrangement 7.6 detects the motion of this reference marking R over the length of one code element C2.

The reference marking R is a partial interruption of the periodicity of the incremental graduation 6. This interruption, in this example, is a blackening of an intrinsically transparent site within the graduation period P1. The higher-order periodicity of the series of graduation periods P1-P8 is not interfered with by this partial interruption.

The detection of the shift in the reference marking R within the detector arrangement 7.6 over a length of one code element C2 is effected by evaluating the analog scanning signals of the detector elements A-D within P1-P8. These scanning signals in the first group of four A-D within the length of one code element C2 are designated as A1-D1, those of the second, next group of four A-D are designated as A2-D2, and those of the eighth group of four A-D are designated as A8-D8.

The reference marking R interferes with the continuous periodic course of the scanning signals A1-D8 at only a single site within a length of the code element C2, and the site of this interference is ascertained in an evaluation unit 20 shown in Fig. 3. The particular group of four 1-8 of detector elements A, B, C, D in which the interference is located is detected; that is, one of the eight detector regions 1-8 is defined unambiguously. In other words, this detection determines an absolute position value Z with a

medium resolution, such that the combination of CW and Z as well as Q yields an unambiguous absolute position.

With the position measuring instrument designed according to the invention, a coarse absolute position value CW with a first increment width can thus be determined. This increment width is furthermore resolved in absolute form by scanning the incremental track 6. The scanning signals A1-D8 are processed in the evaluation unit 8 (Fig. 1) in such a way that a mean absolute value Z with a second increment width is ascertained, along with a fine absolute value Q with a third increment width, which in turn resolves the second increment width absolutely and more finely.

From Figs. 3-5, one possible way of determining the position value Z will be further explained. Since the reference marking R is blackening, position-dependent scanning signals A1-D8 within a single group 1-8 are varied by means of reducing the amplitude. A determination circuit 20 is provided for finding this detector group 1-8. This determination circuit 20 includes a first component 20.1, to which in-phase scanning signals A1-A8 of the eight groups 1-8 are delivered. The component 20.1 determines which scanning signal from A1-A8 has the minimal amplitude. In the same way, in further components 20.2, 20.3 and 20.4, the minimum scanning signals from B1-B8, C1-C8, and D1-D8 are determined.

To enable this determination in every position within a graduation period P1 with great certainty, the following provision is especially advantageous:

It is known that within one graduation period P1, a variation R in the periodicity is incorporated only in part. A control unit 30 is now provided, which assures that within one graduation period P1-P8, it is always the in-phase

scanning signals of groups 1-8 in which the signal interference is in every case contained in the form of the maximum amplitude reduction that are compared with one another. For explaining this subject matter, in Figs. 4a-4d, four different positions POS1-POS4 of the detector arrangement 7.6 relative to the incremental graduation 6 are shown. In the first position POS1, the detector element A and B is located facing the reference marking R, so that within the in-phase scanning signals A1-A8 and the in-phase scanning signals B1-B8, a single one of the scanning signals has the greatest difference in amplitude from the other seven scanning signals. For ascertaining the position Z, the component 20.1 is thus used in position POS1. Fig. 5 shows which detector elements A, B, C, D and scanning signals are used in which position POS1-POS4. Since within each position POS1-POS4, two detector elements A, B, C, D and scanning signals can be used, it is also possible in this example to generate redundant information. The positions POS1-POS4 within one graduation period P1-P8 are unambiguously determined by the interpolation value Q.

For better explanation of the principle of the invention, the detector arrangements 7.5, 7.6 in Fig. 2 extend over only the length of one code element C2. For forming the code word CW, a plurality of code elements C1, C2, C3 must be scanned simultaneously, so that in practice, the detector arrangement 7.5 extends over a plurality of code elements C1, C2, C3. This space can now also be used advantageously for scanning the incremental graduation 6, by repeating the arrangement of the eight detector groups 1-8 multiple times in the measurement direction X. By adding together in-phase scanning signals of groups 1-8 in the various arrangements, the signal generation is made

relatively invulnerable to partial soiling. Scanning the reference marking R also becomes very invulnerable to soiling, since it is scanned multiple times over the entire scanning range, and therefore soiling of one reference marking R does not yet cause any signal failure.

In Fig. 6, the principle of this multiple scanning is illustrated. Within the length of the scanning field 7, the reference marking R is scanned four times. The length of the scanning field 7 is selected as four times the spacing of the reference marking R so that in every position, an equal number of reference markings R will be scanned. In Fig. 6, one of the analog scanning signals A is shown.

An advantageous disposition and evaluation of the code 5 will now be described in further detail.

Fig. 7 shows an instantaneous position of the code 5 relative to the scanning device 2. The detector elements D1-D11 are disposed in succession, at a spacing of half the width of one partial region C1A-C3B of the code 5. This assures that in every position, at least one detector element D1-D11 is unambiguously associated with one partial region C1A-C3B and does not scan a transition between two partial regions C1A-C3B. In the position shown, the partial region C1A is being scanned by the detector element D1, while the partial region C1B is being scanned by the detector element D3. The detector elements D1, D3 detect the light distribution, and as a function of the light intensity, they generate an analog scanning signal S1A, S1B in proportion to the light intensity. Since the two partial regions C1A and C1B are embodied as complementary to one another, the intensity of the scanning signals S1A and S1B is also inverse to one another; that is, the signal levels are spaced far apart from one another.

This signal spacing is now utilized to generate the binary information  $B_1$ , by checking which of the two scanning signals  $S_{1A}$ ,  $S_{1B}$  of the code element  $C_1$  is the greater. This checking can be done by division or subtraction. In this example, subtraction is used, for which purpose, a trigger component  $T_1$  serves as a comparison device in Fig. 7. The trigger component  $T_1$  generates  $B_1 = 0$  if  $S_{1A}$  is less than  $S_{1B}$ , and it generates  $B_1 = 1$  if  $S_{1A}$  is greater than  $S_{1B}$ . In the same way, binary data  $B_2$  and  $B_3$  are obtained by scanning the code elements  $C_2$ ,  $C_3$  and comparing the analog scanning signals  $S_{2A}$ ,  $S_{2B}$ ;  $S_{3A}$ ,  $S_{3B}$  of the partial regions  $C_{2A}$ ,  $C_{2B}$ ;  $C_{3A}$ ,  $C_{3B}$  of each code element  $C_2$ ,  $C_3$  by means of trigger components  $T_2$ ,  $T_3$ .

Thus a first digital value is assigned to a first sequence of the complementary partial regions  $C_{1A}$ ,  $C_{1B}$ ;  $C_{2A}$ ,  $C_{2B}$ ;  $C_{3A}$ ,  $C_{3B}$ , and a second digital value is assigned to a second sequence of the complementary partial regions  $C_{1A}$ ,  $C_{1B}$ ;  $C_{2A}$ ,  $C_{2B}$ ;  $C_{3A}$ ,  $C_{3B}$ . In this example, the value 0 is assigned to the sequence opaque  $\rightarrow$  transparent, and the value 1 is assigned to the sequence transparent  $\rightarrow$  opaque.

Since the two partial regions  $C_{1A}$ ,  $C_{2A}$ ,  $C_{3A}$  on the one hand and  $C_{1B}$ ,  $C_{2B}$ ,  $C_{3B}$  on the other of each code element  $C_1$ ,  $C_2$ ,  $C_3$  are complementary to one another, the signal-to-noise ratio of the scanning signals  $S$  is very high. A variation in the light intensity of the light source 3 affects the scanning signals  $S$  of both partial regions  $C_{1A}$ ,  $C_{1B}$ ;  $C_{2A}$ ,  $C_{2B}$ ;  $C_{3A}$ ,  $C_{3B}$  equally.

Because of the complementary design of each two partial regions  $C_{1A}$ ,  $C_{1B}$ ;  $C_{2A}$ ,  $C_{2B}$ ;  $C_{3A}$ ,  $C_{3B}$  of a code element  $C_1$ ,  $C_2$ ,  $C_3$ , analog signals  $S$  whose difference exceeds a predetermined value must be generated in each case from scanning of these partial regions  $C_{1A}$ ,  $C_{1B}$ ;  $C_{2A}$ ,  $C_{2B}$ ;  $C_{3A}$ ,

C3B, if the position measuring instrument is functioning correctly. By observation of this differential value, good error checking is possible. The basis of this error checking is that it can be assumed that if the differential value fails to be attained by a predetermined amount, the binary information B1, B2, B3 is uncertain, and for that binary information B1, B2, B3, an error signal is therefore generated.

The principle of error checking will now be briefly explained. The analog scanning signals S1A and S1B of the code element C1 are delivered to an error checker. The error checker compares S1A and S1B by subtraction (S1A - S1B) and checks whether the amount of the difference exceeds a predetermined comparison value, or not. If the differential amount (S1A - S1B) does not exceed the predetermined comparison amount, an error signal is output.

Taking the detector elements D1 and D2 as an example, it is clearly apparent from Fig. 7 that upon a shift in the code 5 by the length of one partial region C1A, C1B; C2A, C2B; C3A, C3B to the left, the detector element D1 scans the partial region C1B, while the detector element D3 scans the partial region C2A, or in other words partial regions of two code elements C1, C2 are scanned. The trigger component T1 is therefore unable to furnish binary information B1, B2, B3 that is assigned to one code element C1, C2, C3. Provisions will now be explained with which it is assured that for generating code words, the correct detector elements D1-D11 will be used, or in other words the detector elements D1-D11 that each scan the partial regions of a single code element C1, C2, C3.

From Figs. 8 and 9a-9d, a preferred provision for this will now be described. As already explained, the incremental

track 6 is disposed parallel to and next to the code 5. By means of the position value  $Z$ , a distinction between the right and left partial region  $C1A, C1B; C2A, C2B; C3A, C3B$  of one code element  $C1, C2, C3$  can now easily be made. The position value  $Z$  defines the order of the partial regions  $C1A, C1B; C2A, C2B; C3A, C3B$  unambiguously and serves as a control signal for defining those detector elements  $D1-D11$  from which a correct code word  $CW$  can be generated. That is, the control signal  $Z$  defines which scanning signals  $S$  will be compared with one another, and from which scanning signals  $S$  digital values  $B1, B2, B3$  for the code word  $CW$  can be obtained.

To further explain this method, in Figs. 9a-9d four different positions of the code 5 relative to the detector arrangement 7.5 are shown. The detector elements  $D1-D11$  are disposed in the measurement direction  $X$  at spacings equivalent to half the length of one partial region  $C1A, C1B; C2A, C2B; C3A, C3B$ , and two detector elements  $D1-D11$  each, which are disposed at a mutual spacing in accordance with the length of one partial region  $C1A, C1B; C2A, C2B; C3A, C3B$ , are connected differentially.

In Fig. 9a, the first position is shown. A control unit  $M$ , as a function of the position information  $Z$ , selects the detector elements  $D4$  and  $D6$ . The bit  $B1$  of the code element  $C1$  is formed by subtraction from detector elements  $D4$  and  $D6$ , or in other words from  $(D4 - D6)$ .

In the second position  $P2$  in Fig. 9b, the control unit  $M$  selects the detector elements  $D3$  and  $D5$ . In the third position in Fig. 9c, the detector elements  $D2$  and  $D4$  are selected for subtraction by the control unit  $M$ . In the fourth position in Fig. 9d, the detector elements  $D1$  and  $D3$  are selected.

In the same way, the correct detector elements are ascertained for forming the further bits B<sub>2</sub>, B<sub>3</sub> of the code word CW. For instance, if for forming the bit B<sub>1</sub> the detector elements D<sub>1</sub> and D<sub>3</sub> were selected, then to form the bit B<sub>2</sub>, the detector elements D<sub>5</sub> and D<sub>7</sub> are selected, and for forming the bit B<sub>3</sub>, the detector elements D<sub>9</sub> and D<sub>11</sub> are selected, as shown in Fig. 7. In Fig. 7, only the trigger components T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> used in this instantaneous position are shown.

A further possible way of ascertaining the correct detector elements D<sub>1</sub>-D<sub>11</sub> and the correct analog scanning signals S is for all the detector elements D<sub>1</sub>-D<sub>11</sub>, which are spaced apart from one another by the length of one partial region C<sub>1A</sub>, C<sub>1B</sub>; C<sub>2A</sub>, C<sub>2B</sub>; C<sub>3A</sub>, C<sub>3B</sub>, are compared with one another. The result, at the spacing of one code element C<sub>1</sub>, C<sub>2</sub>, C<sub>3</sub>, is now detector pairs D<sub>1</sub>, D<sub>3</sub> and D<sub>5</sub>, D<sub>7</sub> - in the example of the instantaneous position shown in Fig. 9d - that in the desired way each scan the difference between the partial regions C<sub>1A</sub>, C<sub>1B</sub>; C<sub>2A</sub>, C<sub>2B</sub>; C<sub>3A</sub>, C<sub>3B</sub> of one code element C<sub>1</sub>, C<sub>2</sub>. The further detector pairs D<sub>3</sub>, D<sub>5</sub> scans successive partial regions of two successive code elements C<sub>1</sub>, C<sub>2</sub> and thus, by the error checking explained above, generate an error signal F. In order now to ascertain the correct detector elements D<sub>1</sub>-D<sub>11</sub>, the detector group D<sub>1</sub>, D<sub>3</sub>; D<sub>5</sub>, D<sub>7</sub> in which the fewest error signals occur is looked for. In detail, for performing this second possible provision, the following arrangement and the following method steps are needed:

- Detector elements D<sub>1</sub>-D<sub>11</sub> are disposed in the measurement direction X at intervals equivalent to half the length of one partial region C<sub>1A</sub>, C<sub>1B</sub>; C<sub>2A</sub>, C<sub>2B</sub>; C<sub>3A</sub>, C<sub>3B</sub>;

- the detector elements D1-D11 form a first group (in Figs. 9a-9d, the even-numbered detector elements D2, D4, D6, D8, D10) with a mutual spacing equivalent to the length of one partial region C1A, C1B; C2A, C2B; C3A, C3B;
- the detector elements D1-D11 form a second group (in Figs. 9a-9d, the odd-numbered detector elements D1, D3, D5, D7, D9) with a mutual spacing equivalent to the length of one partial region C1A, C1B; C2A, C2B; C3A, C3B;
- the detector elements D2, D4, D6, D8, D10 of the first group are disposed offset from the detector elements D1, D3, D5, D7, D9 of the second group by half the length of one partial region C1A, C1B; C2A, C2B; C3A, C3B;
- detector elements immediately succeeding one another in one group are each connected differentially;
- of the two groups, the results of comparison of the pairs of detector elements are now used, in a matrix corresponding to the length of one code element C1, C2, C3, to form the code word CW whose series generates the fewest errors F; in Fig. 9d, this is the series (D1 - D3) = B1 (D5 - D7) = B2, etc.

The two partial regions C1A, C1B; C2A, C2B; C3A, C3B of each code element C1, C2, C3 can be embodied as scannable optically; in that case, one partial region is embodied as transparent or reflective to the scanning light, while the other partial region is embodied as opaque or nonreflective.

The invention can be especially advantageously used with the optical scanning principle. However, the invention is not limited to this scanning principle, but can also be used with magnetic, inductive and capacitive scanning principles.

The position measuring instrument can be used for measuring linear or rotary motions. The objects to be measured can be the table and carriage of a machine tool, a coordinate measuring machine, or the rotor and stator of an electric motor.

Claims

1. A position measuring instrument, having

- a periodic incremental graduation (6) with a plurality of graduation periods (P1-P8) within one measurement range (C1, C2, C3);
- a reference marking (R) disposed within the measurement range (C1, C2, C3) and integrated with the incremental graduation (6);
- an arrangement (7.6) of detector elements (A, B, C, D) over at least the length of the measurement range (C1, C2, C3) for generating a plurality of periodic scanning signals (A1-D8) of which at least one is modified locally by the reference marking (R);
- an evaluation device (8) for receiving the scanning signals (A1-D8) and for detecting the at least one scanning signal (A1, B1), modified by the reference marking (R), from scanning signals (A1-D8) and for determining an absolute position (Z) of the reference marking (R) within the length of the measurement range (C1, C2, C3) as a function of the scanning signal (A1, B1) detected.

2. The position measuring instrument of claim 1, wherein

- within the measurement range (C1, C2, C3), N graduation periods (P1-P8) are disposed, where N > 1 and is an integer;

- the arrangement (7.6) of detector elements (A, B, C, D) over the length of the measurement range (C1, C2, C3) forms N groups (1-8), and each group (1-8) of detector elements (A, B, C, D) extends over the length of one graduation period (P1-P8);

- within each group (1-8), a plurality of detector elements (A, B, C, D) are spaced apart from one another by a fraction of one graduation period (P1-P8), in order within one group (1-8) to generate a plurality of periodic scanning signals (A1, B1, C1, D1 - A8, B8, C8, D8) phase-offset from one another.

3. The position measuring instrument of claim 2, wherein in-phase scanning signals (A1-A8; B1-B8; C1-C8; D1-D8) of all the groups (1-8) are added together to form a common summation signal (PA, PB, PC, PD).

4. The position measuring instrument of claim 3, wherein the summation signals (PA, PB, PC, PD) are delivered to an interpolation unit (9) for determining an absolute position (Q) within one graduation period (P1-P8).

5. The position measuring instrument of claim 2, wherein in-phase scanning signals (A1-A8; B1-B8; C1-C8; D1-D8) of the N groups are delivered to the evaluation unit (8), which compares the respective in-phase scanning signals (A1-

A8; B1-B8; C1-C8; D1-D8) with one another and from the result of the comparison determines one scanning signal (A1, B1) in the group (1-8) which is modified by the reference marking (R), and this group (1-8) determines the position (Z) of the reference marking (R) within the length of the measurement range (C1, C2, C3).

6. The position measuring instrument of claim 5, wherein the reference marking (R) is an interference in the periodicity at one site within one graduation period (P1) of the incremental graduation (6), and in-phase scanning signals (A1-A8; B1-B8), determined as a function of the site of the interference within this graduation period (P1), of detector elements (A, B, C, D) of the N groups (1-8) that scan this site within each of the N graduation periods (P1-P8) are compared with one another.

7. The position measuring instrument of claims 4 and 6, wherein the scanning signals (A1-D8) to be compared with one another for determining the position (Z) are determined by the absolute position (Q) that is formed by means of the interpolation unit (9).

8. The position measuring instrument of one of the foregoing claims, wherein the reference marking (R) is a variation of an interstice in a series of equally-spaced markings which forms the incremental graduation (6).

9. The position measuring instrument of one of the foregoing claims, wherein the length of the detector arrangement (7.6) is an integral multiple of the spacing of two successive reference markings (R).

10. The position measuring instrument of one of the foregoing claims, wherein parallel to and next to the incremental graduation (6), an absolute code (5) for absolute position measurement is disposed at measurement increments in accordance with the length of one measurement range (C1, C2, C3).

11. The position measuring instrument of claim 10, wherein the absolute code (5) is a single-track sequential code with successive code elements (C1, C2, C3).

12. A method for position measurement, having the following method steps:

- scanning a plurality of graduation periods (P1-P8) of one incremental graduation (6) by means of a detector arrangement (7.6) extending over the length of one measurement range (C1, C2, C3), a reference marking (R) being integrated with one of the graduation periods (P1), and generating a plurality of periodic scanning signals (A1-D8), of which at least one is locally modified by the reference marking (R);

- detecting the at least one scanning signal (A1, B1), modified by the reference marking (R), from among the scanning signals (A1-D8); and

- determining an absolute position (Z) of the reference marking (R) within the length of the measurement range (C1, C2, C3) as a function of the scanning signal (A1, B1) detected.

13. The method of claim 12, wherein by means of the scanning of a plurality of graduation periods (P1-P8) in the incremental graduation (6), a plurality of scanning signals (A1-D8) phase-offset from one another are generated within each graduation period (P1-P8) of the measurement range (C1, C2, C3).

14. The method of claim 13, wherein scanning signals (A1-A8; B1-B8; C1-C8; D1-D8) in-phase with one another in all the graduation periods (P1-P8) are added together to form a common summation signal (PA, PB, PC, PD).

15. The method of claim 14, wherein the summation signals (PA, PB, PC, PD) are delivered to an interpolation unit (9), and an absolute position (Q) within one graduation period (P1-P8) is ascertained.

16. The method of claim 13, wherein scanning signals (A1-A8; B1-B8; C1-C8; D1-D8) in-phase with one another in all the graduation periods (P1-P8) are compared with one another, and from the comparison, the scanning signal (A1, B1) whose amplitude is modified by the reference marking (R) is determined.

17. The method of claims 15 and 16, wherein by means of the absolute position (Q) within one graduation period (P1-P8), the scanning signals (A1-A8; B1-B8) within one graduation period (P1-P8) that are to be compared with one another are determined for forming the position (Z).

A reference marking (R) is integrated with one graduation period (P1) of an incremental graduation (6). With a detector arrangement (7.6), the incremental graduation (6) is scanned, yielding a plurality of scanning signals (A1-D8), which are delivered to an evaluation unit (8). From the scanning signals (A1-D8), the evaluation unit (8) generates an absolute position (Q) within one graduation period (P1-P8) as well as a further absolute position (Z), which absolutely determines the site of the reference marking (R) along the detector arrangement (7.6). (Fig. 1)

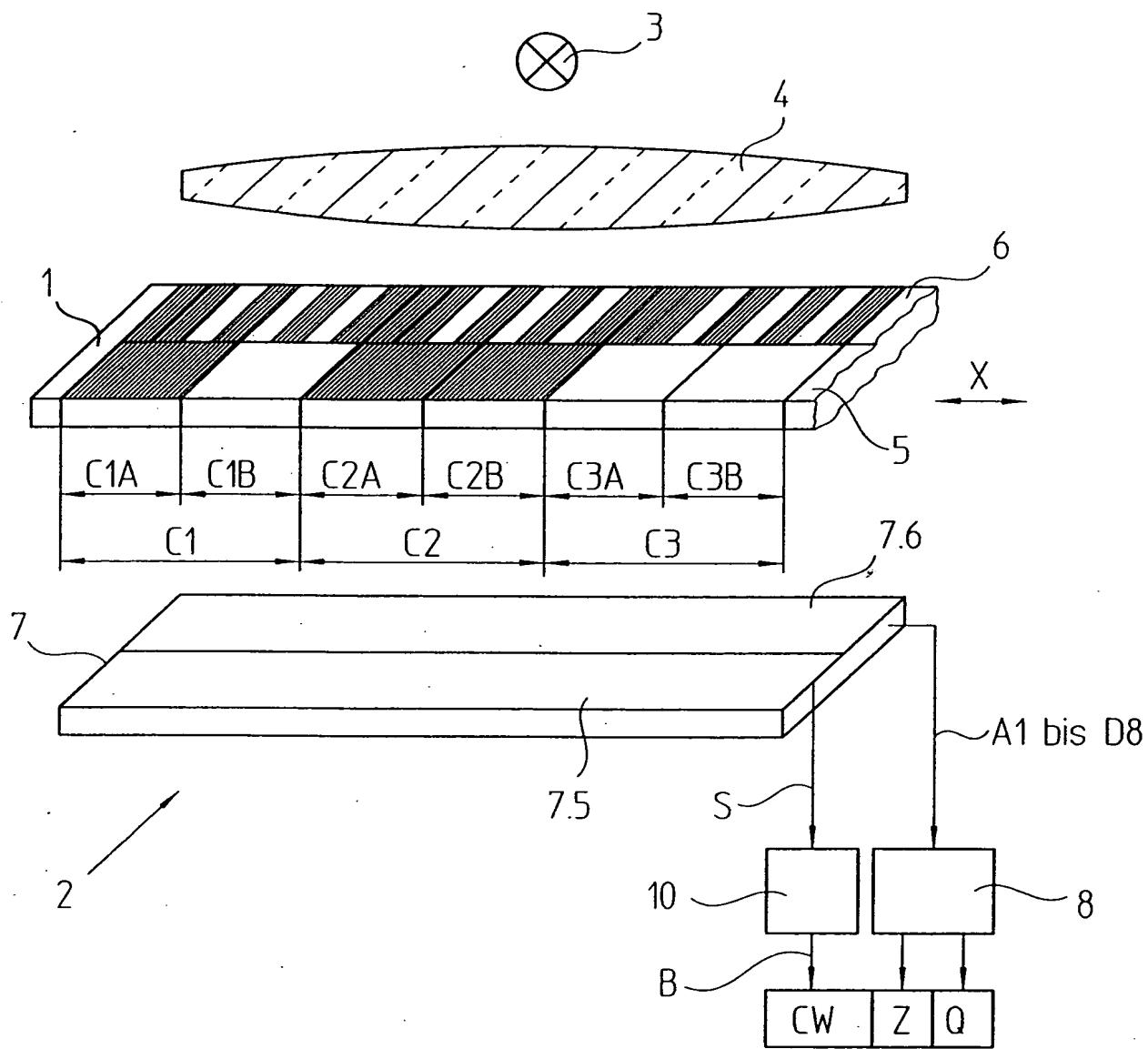


FIG. 2

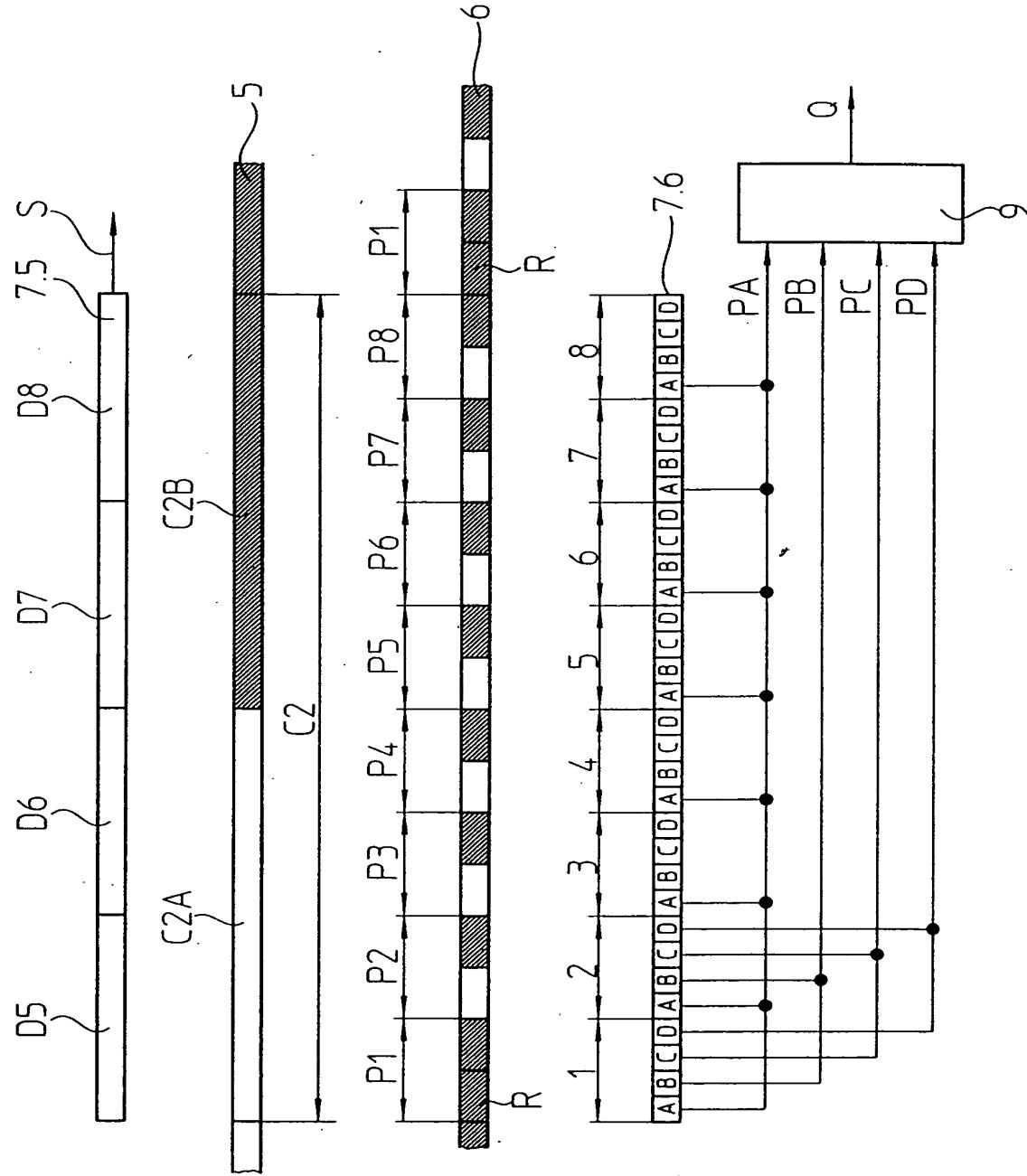


FIG. 3

3/9

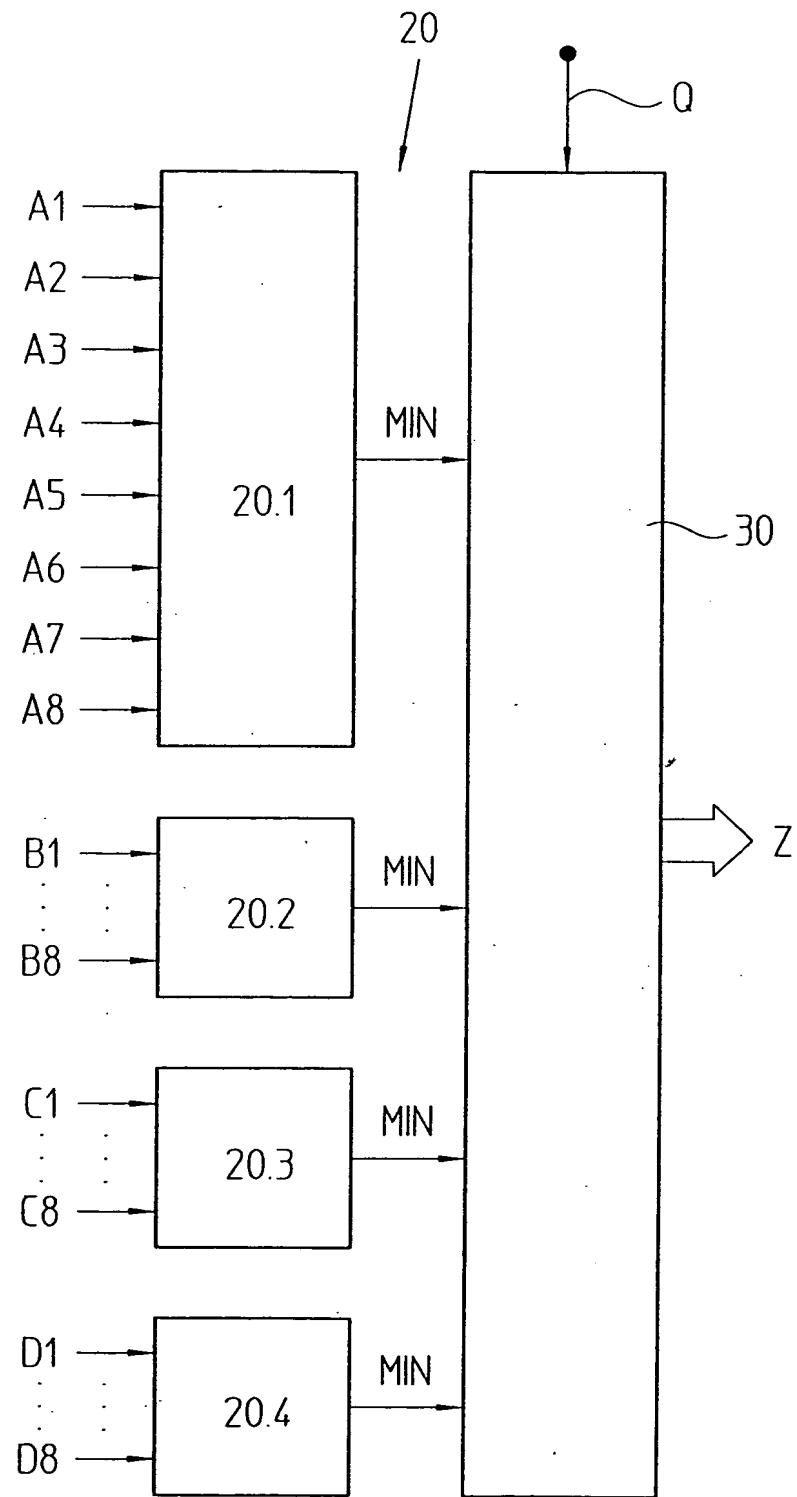


FIG. 4a

4/9

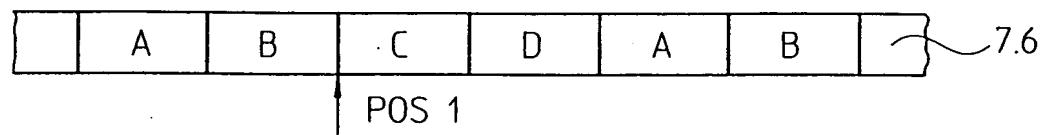
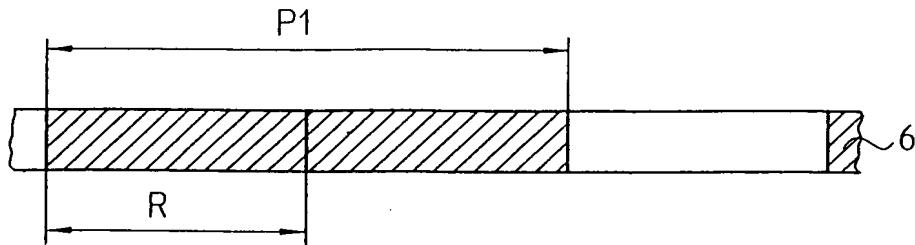


FIG. 4b

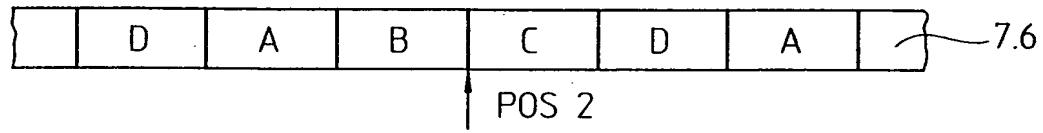


FIG. 4c

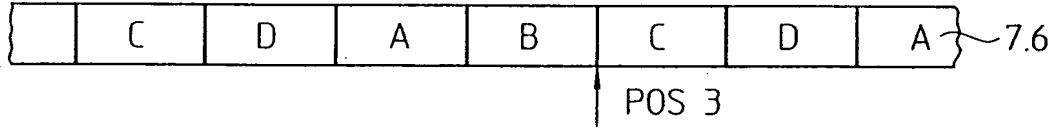


FIG. 4d

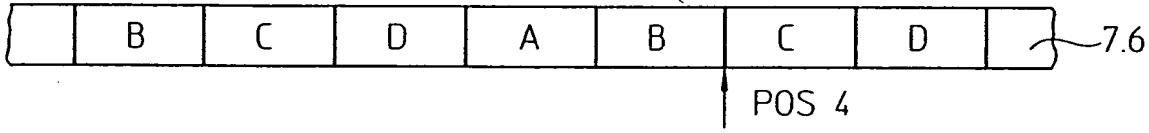


FIG. 5

	POS1	POS2	POS3	POS4
A	X	X	-	-
B	X	-	-	X
C	-	-	X	X
D	-	X	X	-

FIG. 6

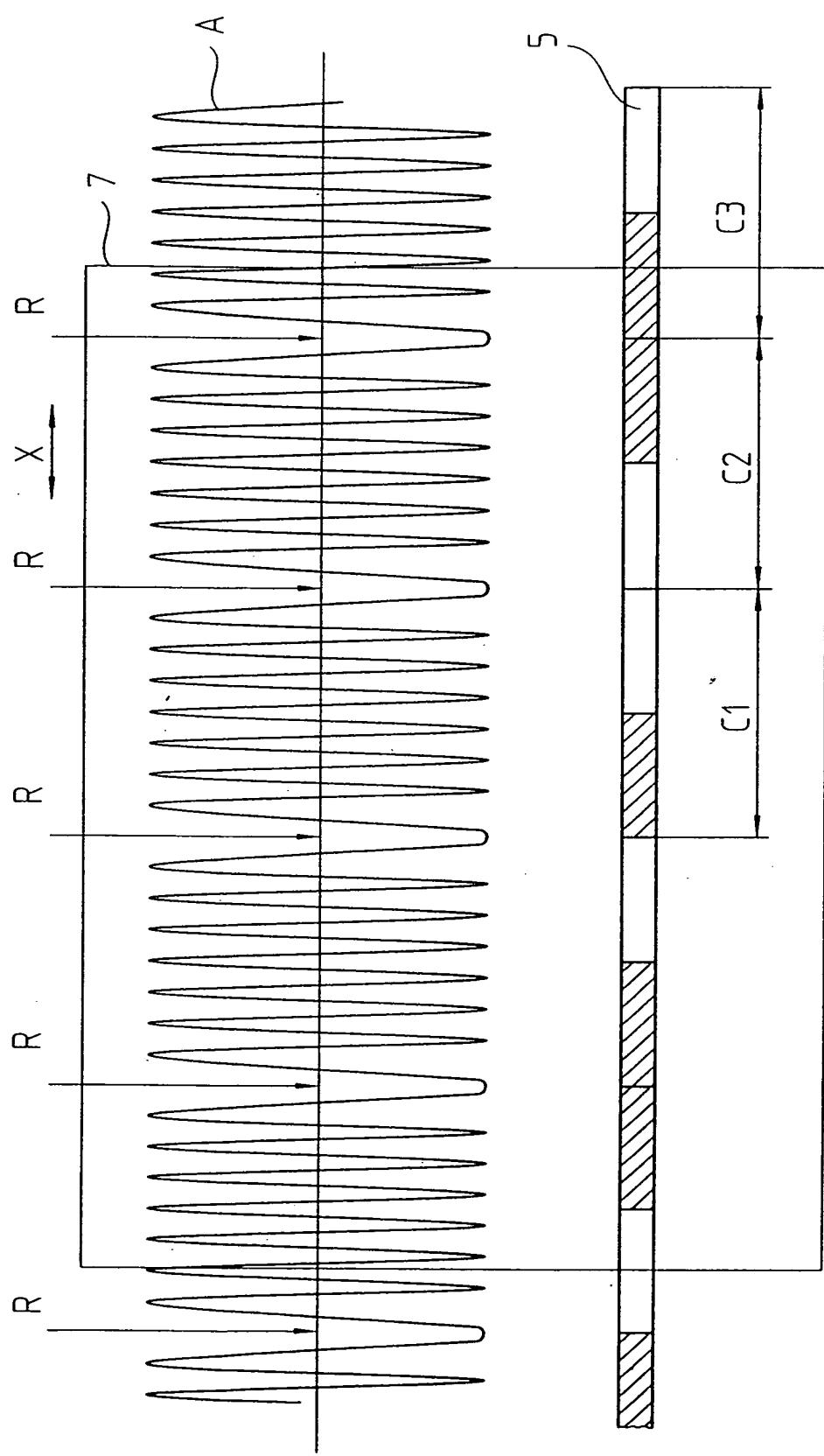


FIG. 7

6/9

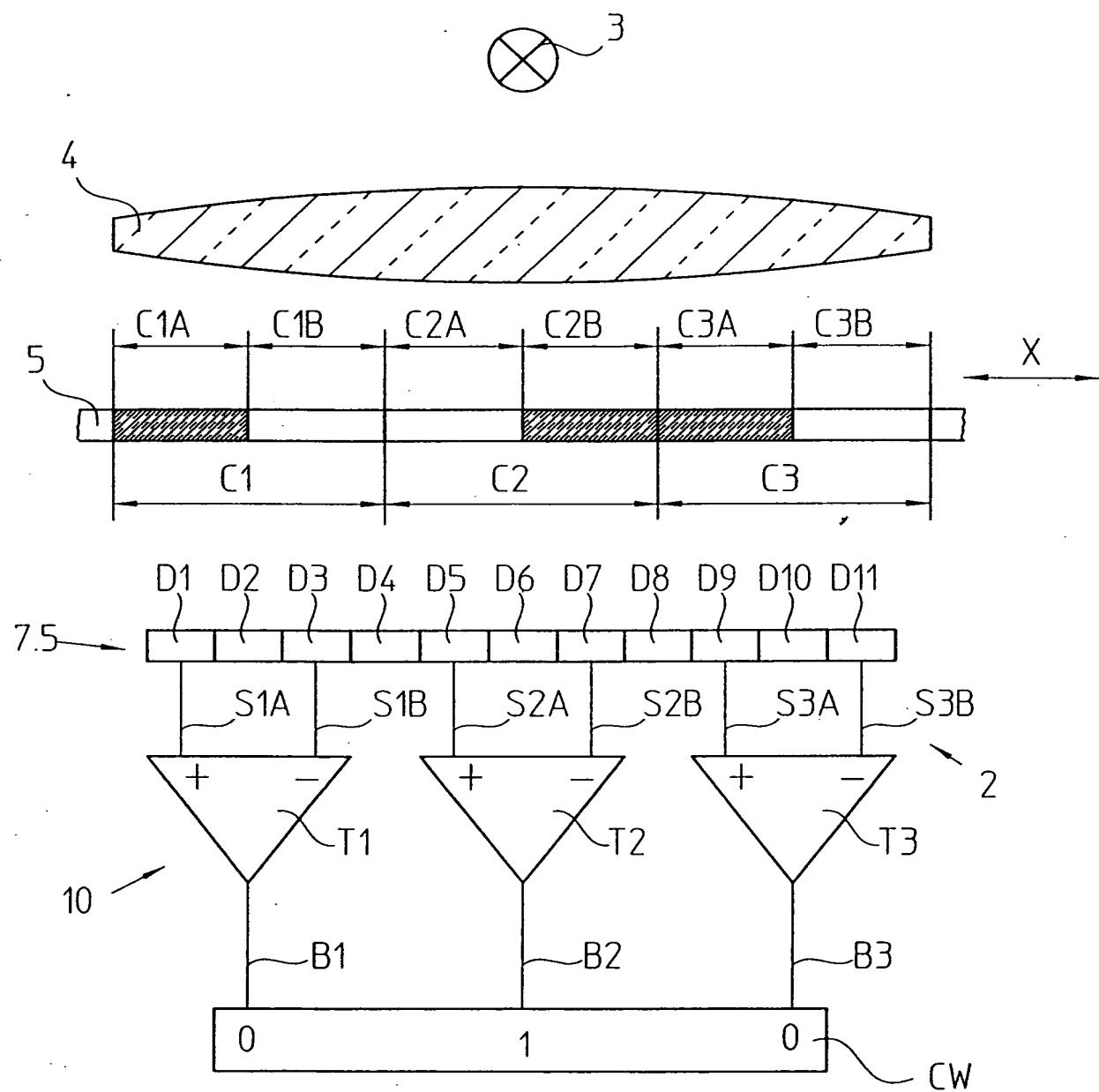


FIG. 8

7/9

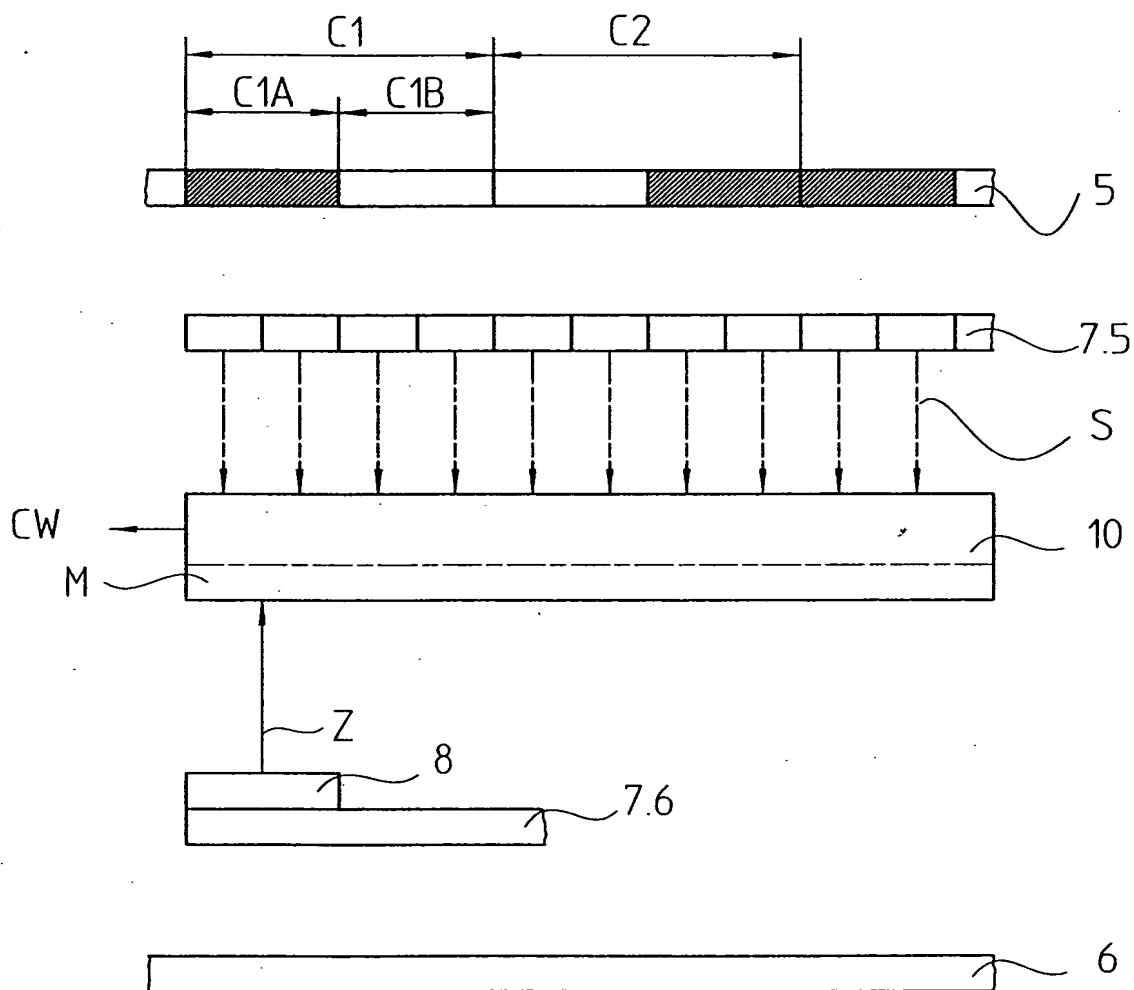


FIG. 9a

8/9

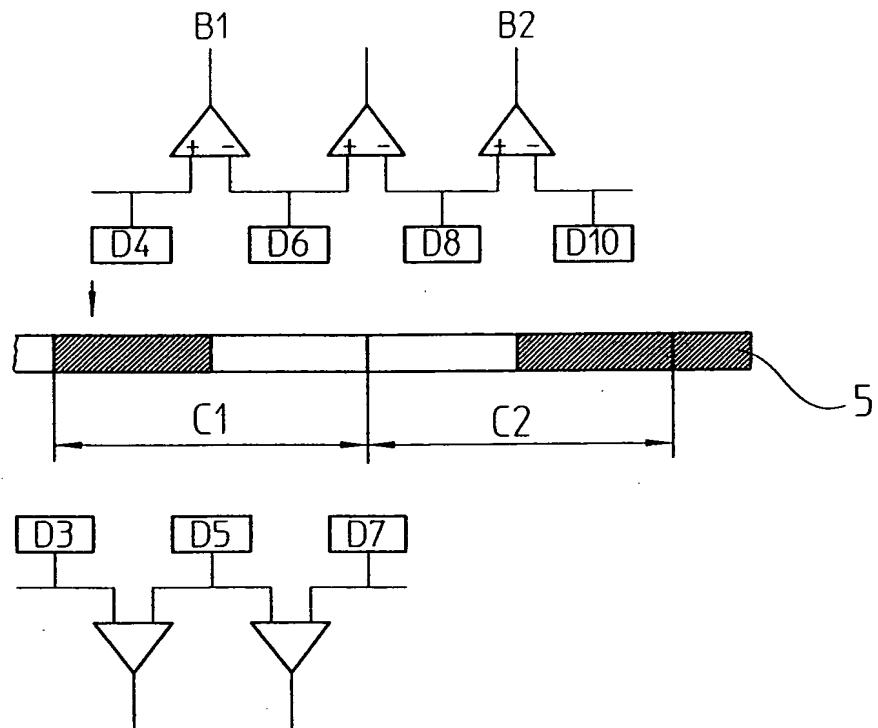


FIG. 9b

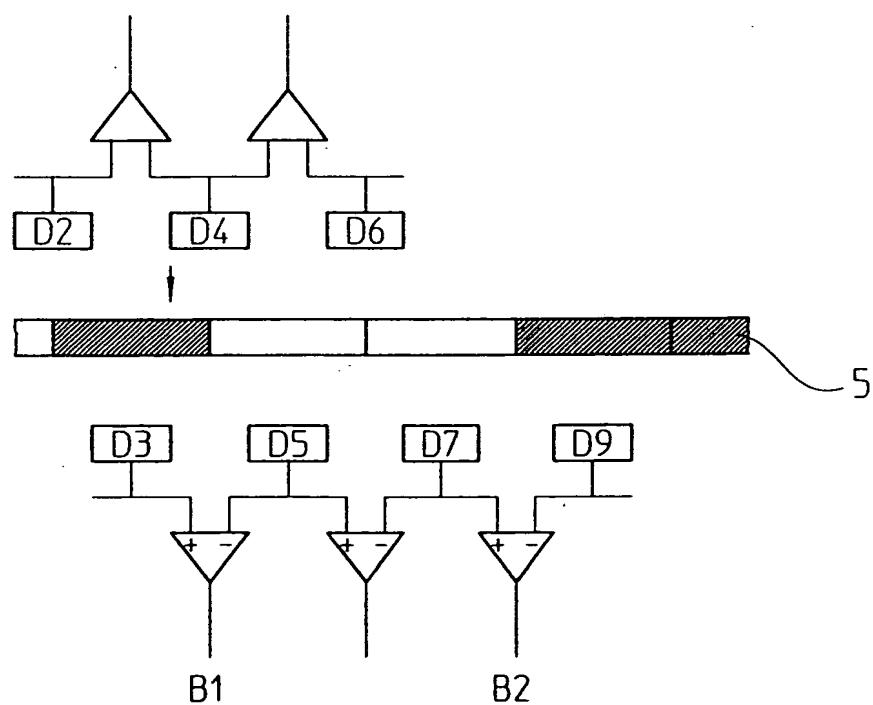


FIG. 9c

9/9

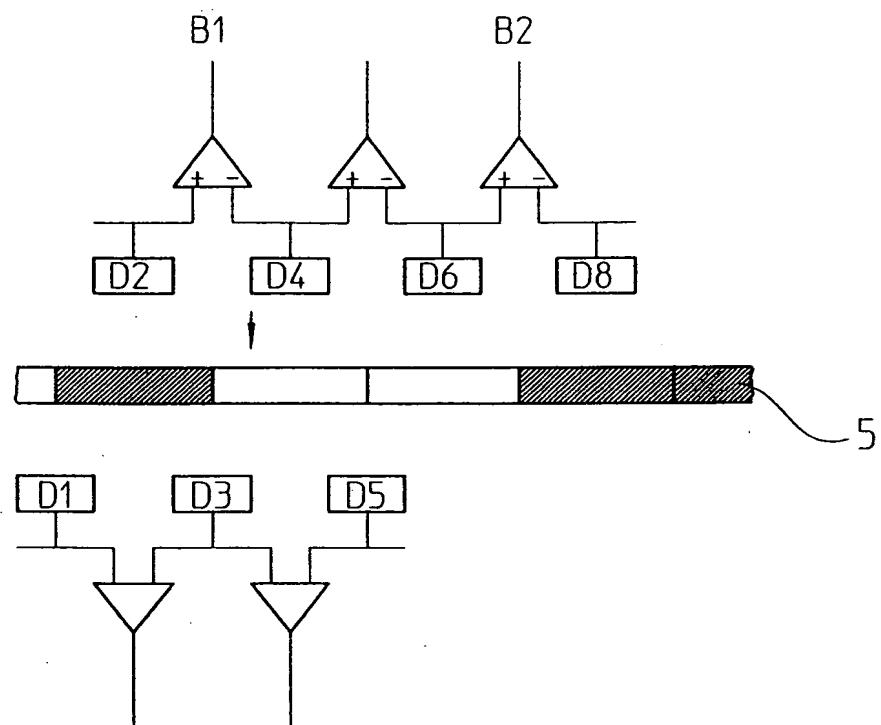


FIG. 9d

